Space Imaging
IKONOS Spatial Characterization

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Topical Agenda

- System Requirements
- Pre Flight Simulation & Sensitivity Analysis
- Target Characteristics
- On - orbit Results

Specification and Individual Contributors

The end to end IKONOS System, as an Imager, is specified in terms of:

- **a pixel to pixel, peak to peak signal to rms noise of 10 to 1**
- **for a target contrast ratio at the entrance pupil of 2 : 1**
- **at solar elevations .GE. 30 degrees**

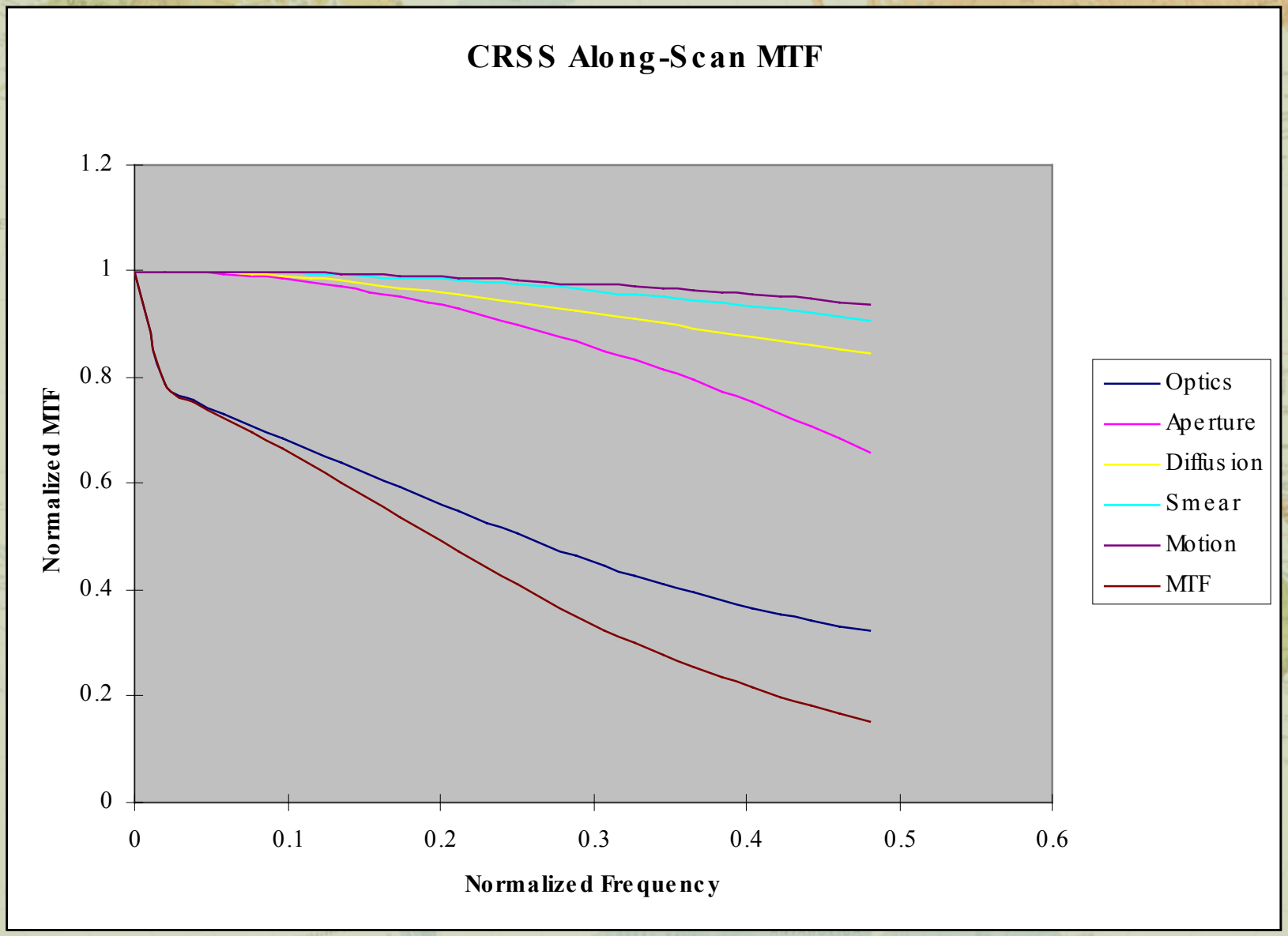
Payload Pan MTF at 24 TDI was predicted to be 0.154 at Nyquist:

- **Comprised of:**
  - **Theoretical Optics Design**
  - **Optical Quality Factor**
  - **Defocus error**
  - **Detector Sampling Aperture**
  - **Charge Transfer efficiency**
  - **2 Phase Clock**
  - **Diffusion**

System Pan MTF was predicted to be 0.135 at Nyquist

- **Includes the added effects of:**
  - **Random Motion**
  - **Synchronization**
  - **Resampling and Display**

Component MTF's



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Sensitivity Analysis

First Series of Simulations - reported 29 May 1997

For Target sizing, orientation and Reflectance

Target size -	14 x 10 m and 28 x 20 m
Rotation Angle-	10 degrees
Target C/R -	2:1 and 6:1
Visibility -	4 and 27 km

Second Series of Simulations - reported 11 December 1997

Pixel phasing, noise effects and cropping methods

Target size -	20 x 20 m
Rotation Angle-	4 and 7 degrees
Target C/R -	2:1, 3:1 and 4:1
Visibility -	4 and 27 km

Uncertainty of the Mean

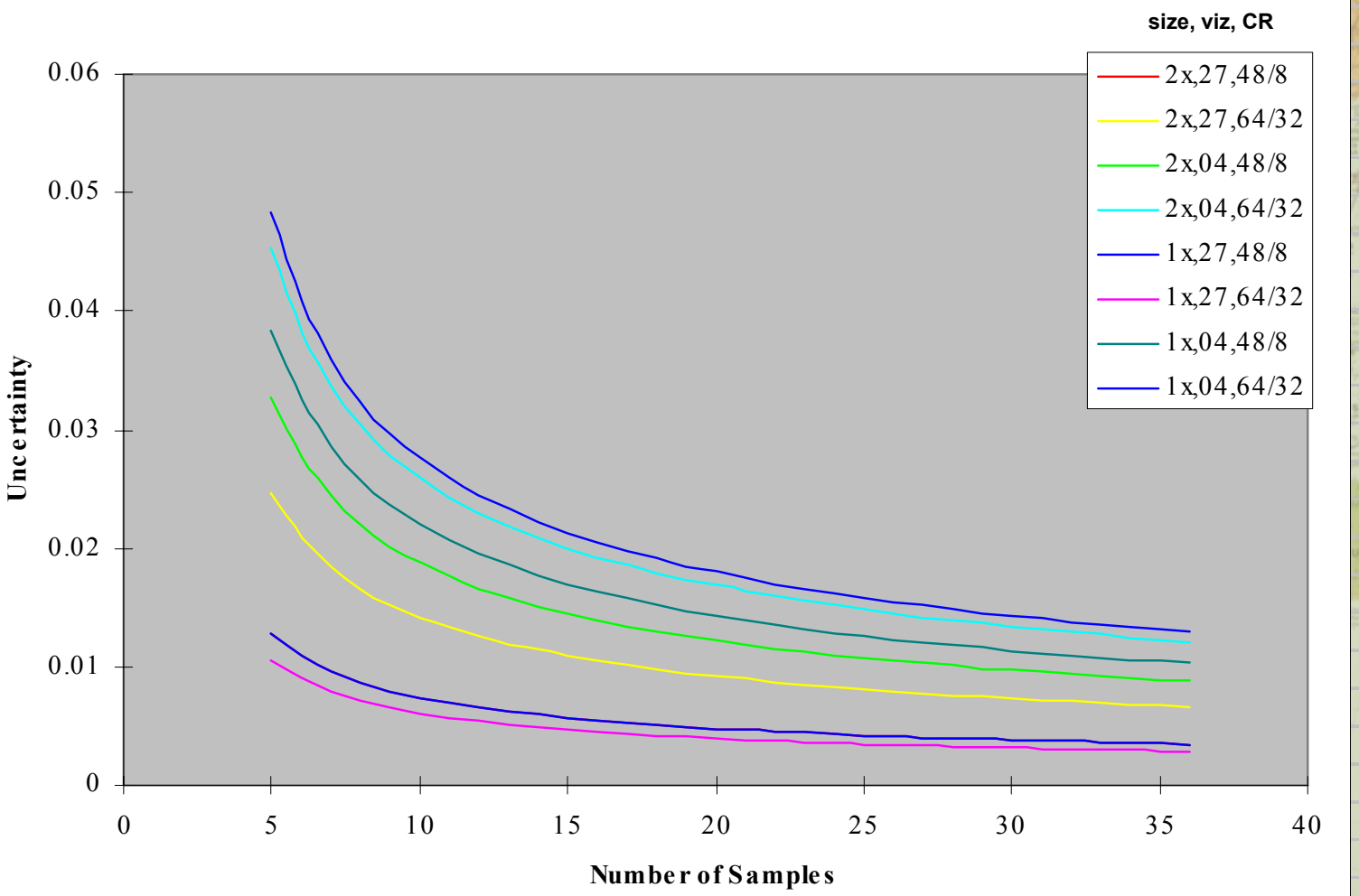
- Determine the uncertainty in the calculated mean MTF as a function of target design parameters and atmospheric effects

- Test Cases and Results

Visibility (km)	Target Size (x WPAFB 14m x 10m)	Reflectance Ratio (%)	Average Standard Deviation	D_MTF at Nyquist	Uncertainty of the Mean (90% Confidence)
27	2	48/08	0.012	-0.021	0.013
27	2	64/32	0.023	0.003	0.025
4	2	48/08	0.031	0.011	0.033
4	2	64/32	0.042	0.002	0.045
27	1	48/08	0.012	-0.019	0.013
27	1	64/32	0.010	-0.036	0.011
4	1	48/08	0.036	-0.019	0.038
4	1	64/32	0.045	-0.023	0.048

- Visibility caused the largest spread in the results

Uncertainty of the Mean vs Sample Size



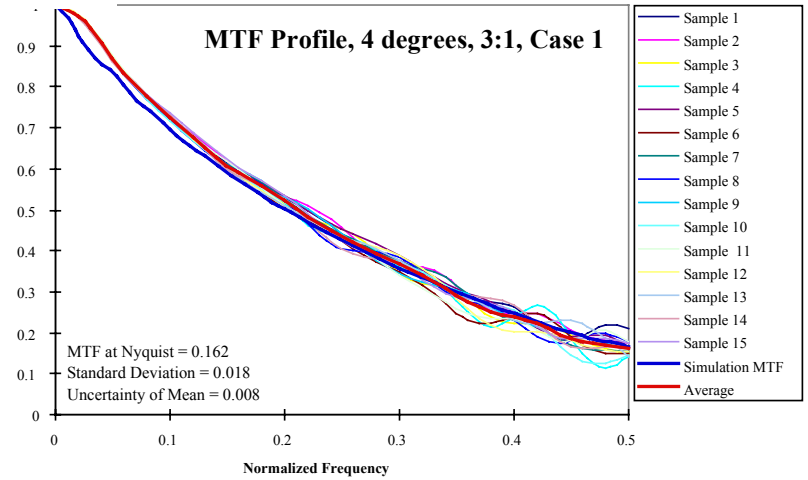
Simulation Matrix - Second Series of Simulations

Case	Angle, CR	Samples	Average Nyquist	Std. Dev.	Unc. of the Mean
Case 1	4, 3:1	15	0.162	0.018	0.008
Case 2	4, 3:1	6	0.160	0.028	0.023
Case 3	4, 2:1	10	0.135	0.034	0.019
Case 3	4, 3:1	20	0.153	0.025	0.010
Case 3	4, 4:1	20	0.156	0.014	0.005
Case 3	7, 2:1	10	0.154	0.029	0.017
Case 3	7, 3:1	10	0.141	0.023	0.013
Case 3	7, 4:1	10	0.141	0.018	0.011
Case 3	4, ALL	50	0.150	0.025	0.006
Case 3	7, ALL	30	0.146	0.024	0.007
Case 3	4&7, 2:1	20	0.145	0.033	0.013
Case 3	4&7, 3:1	30	0.149	0.025	0.008
Case 3	4&7, 4:1	30	0.151	0.017	0.005
Case 3	ALL	80	0.149	0.024	0.005

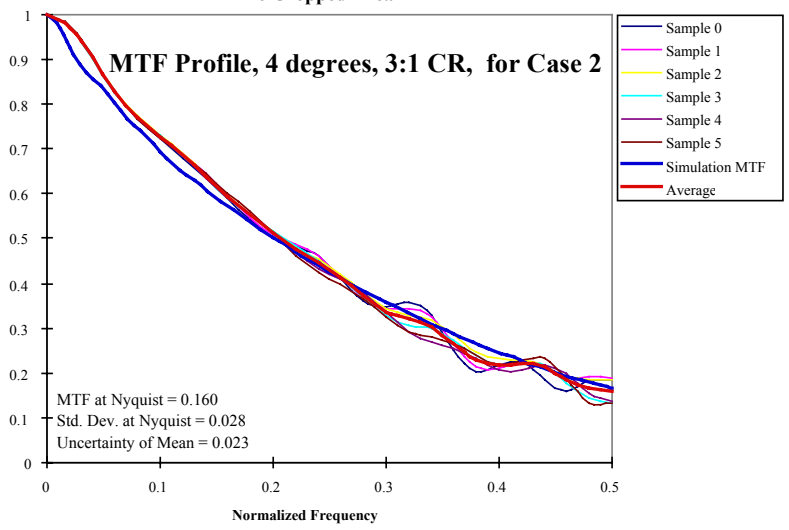
Case 1 - random noise, Case 2 random phasing, Case 3 random noise and phasing

Sample MTF Profile Results

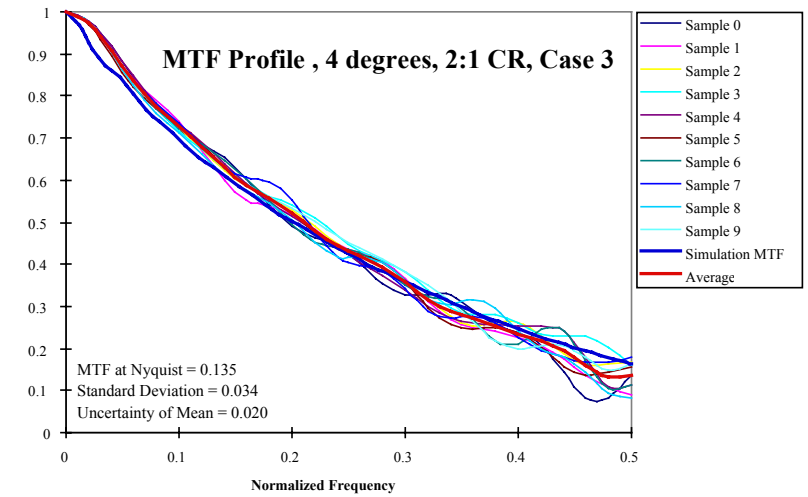
Case 1 (Random Noise, Fixed Phase, 4°, 3:1)
14x26 Cropped Area



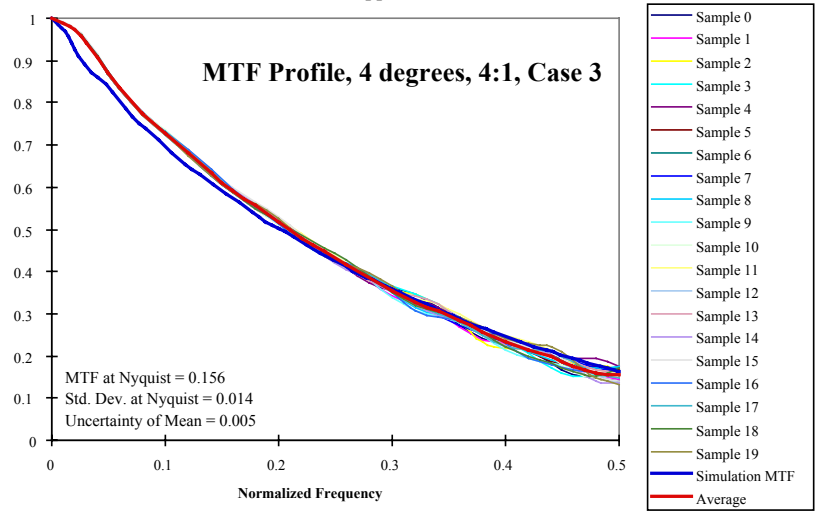
Case 2 (Fixed Noise Seed, Random Phase, 4°, 3:1)
14x26 Cropped Area



Case 3 (Random Noise, Random Phase, 4°, 2:1)
14x26 Cropped Area



Case 3 (Random Noise, Random Phase, 4°, 4:1)
14x26 Cropped Area



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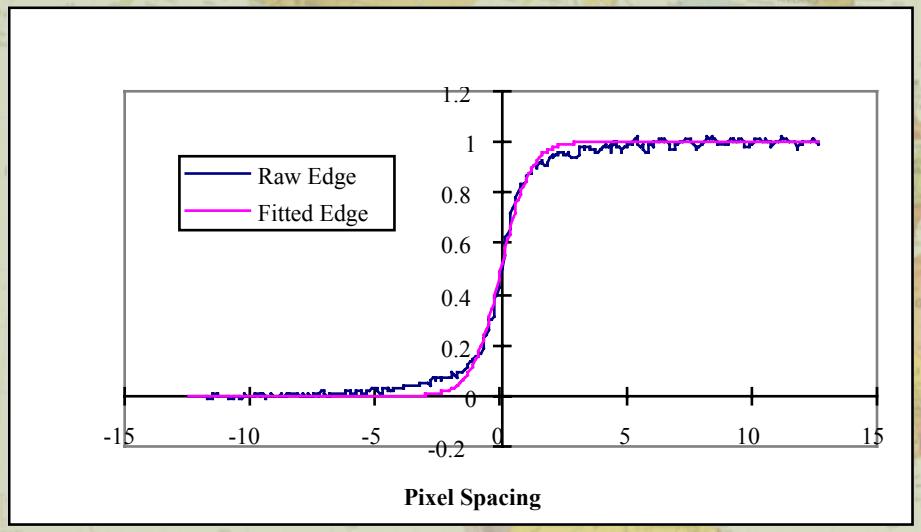
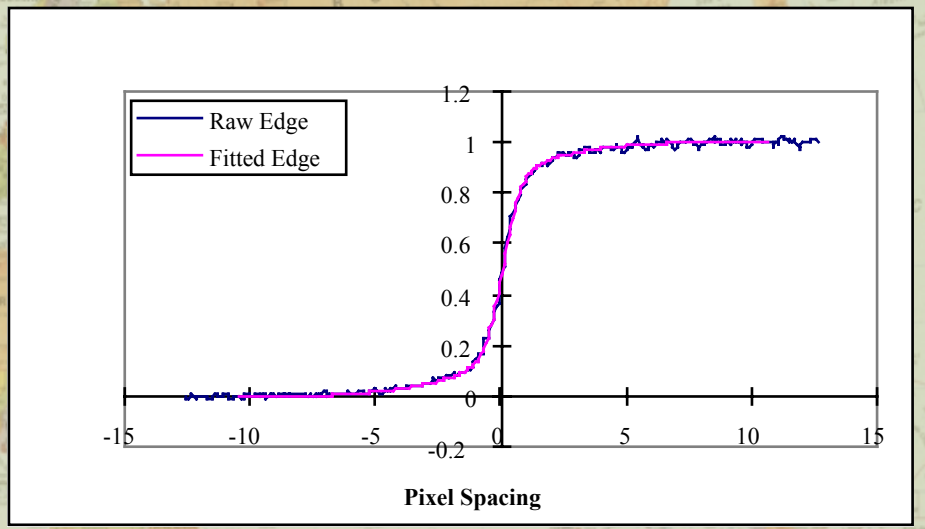
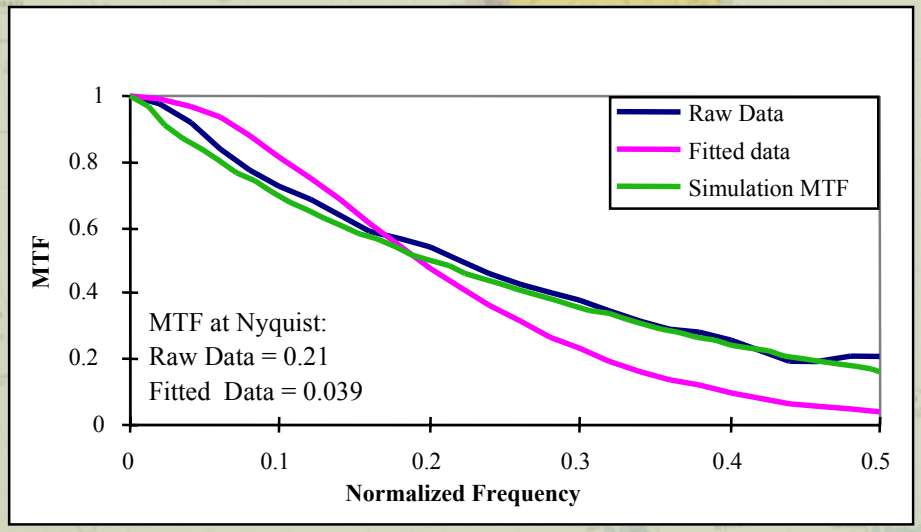
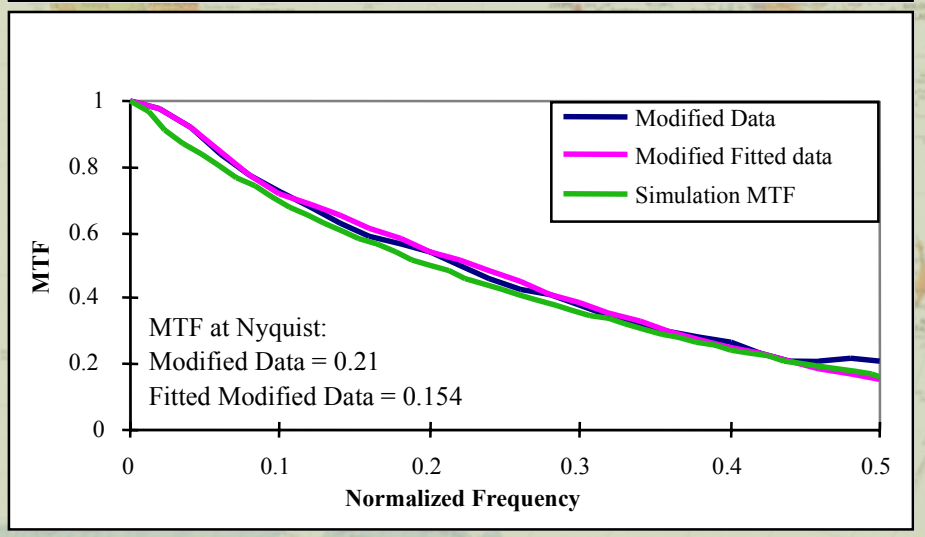
Examples of Data Fitting

- Careful cropping and fitting of the data affects the end results





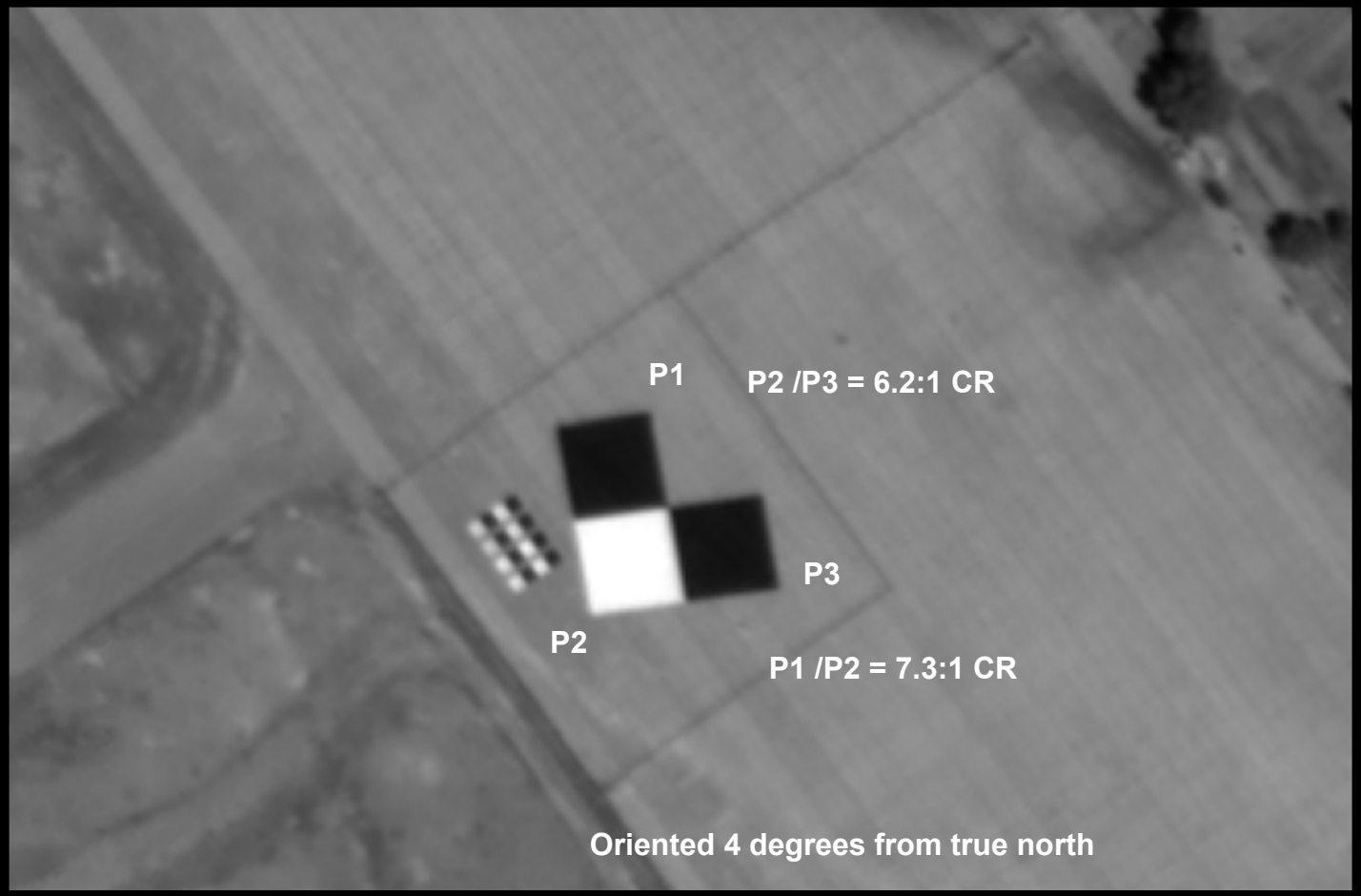




Simulation
Conclusions and Recommendations

- Random noise and phasing compound uncertainty in Nyquist average for the simulated edge measurements
- Technique highly sensitive to cropping area
  - Take care in selecting region
    - Extend width to include enough data points (as a function of angle collected) to account for phasing
  - Modifications in code could reduce sensitivity
    - Artificially extend flat regions of tails in edge profile
    - Set flat regions to a constant
  - Simulation method using discrete functions for applying an MTF to a discrete edge target, etc. causes phasing to be important. Actual IKONOS data will be continuous application of MTF to a continuous target image (then discretely sampled) so phasing effects should be reduced.

Space Imaging Edge Target



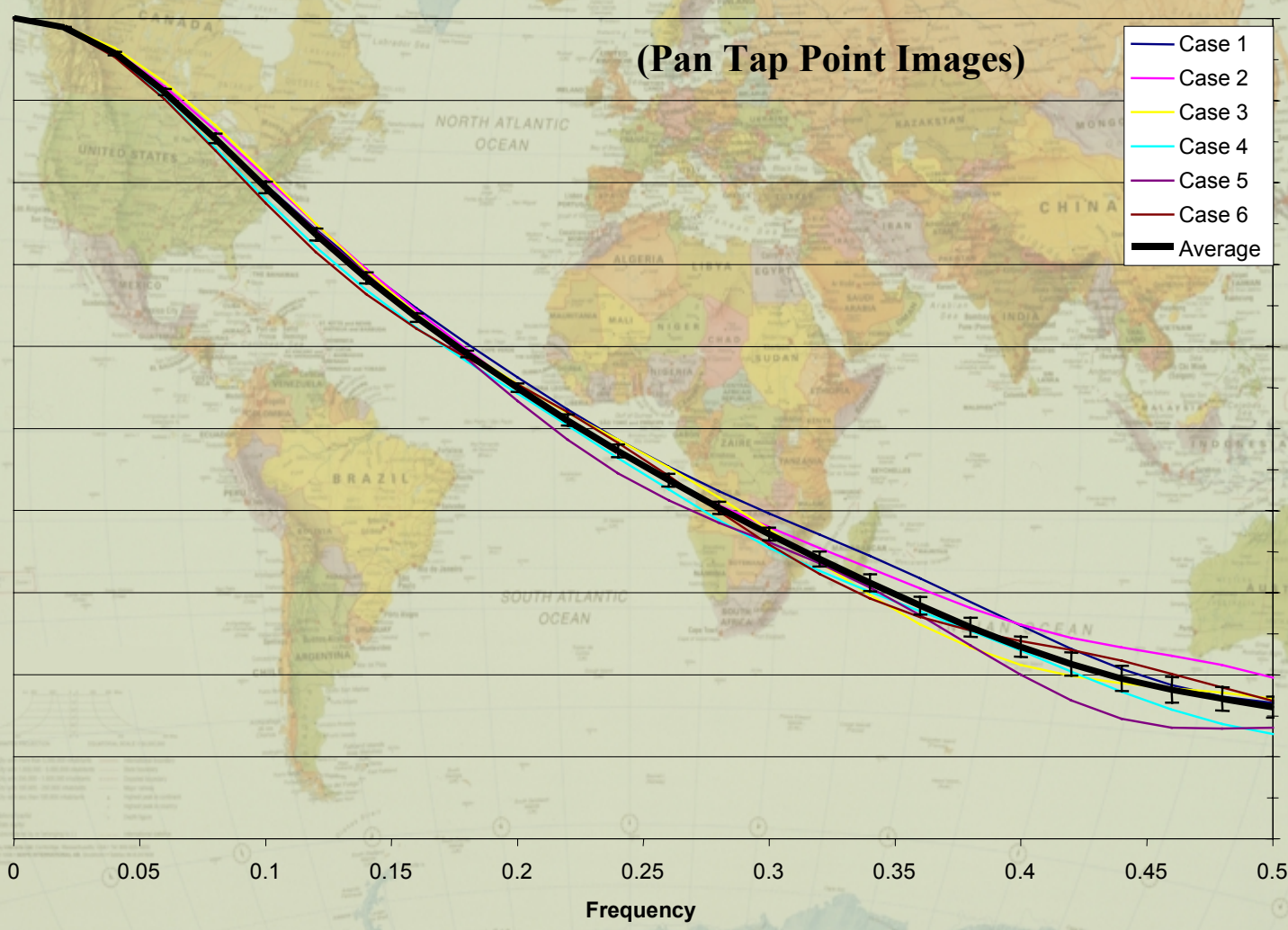
On - Orbit Measured Modulation Transfer Function

The panchromatic MTF was measured using an edge target and Fourier techniques during the on-orbit test program. The MTF was evaluated using "tap-point" data, prior to image synthetic array resampling, to provide a true representation of the collection system performance.

IKONOS Modulation Transfer Function at Nyquist

Band	MTF	Verification Method
Pan	0.17	On-Orbit Test

On - Orbit Measured Modulation Transfer Function



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IKONOS Signal to Noise Ratio

The flat field SNR was measured using the on-board calibration assembly imaging the Sun at an illumination level approximately equivalent to the peak signal level associated with the specification conditions (H + L).

Band	Signal H+L (DN)	rms Noise theo / meas (DN)	Flat Field SNR [L/rms]	Payload + motion p-p Signal/ rms noise
Pan	947	3.16 /3.55	89	15
Blue	1406	3.85 /5.0	94	25
Green	1933	4.51 /4.5	143	41
Red	1395	3.83 /4.5	103	30
NIR	751	2.81 /3.75	67	18

- **The System is Shot noise limited**